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ReCell ADVANCED BATTERY RECYCLING

WHY DIRECT RECYCLING IS PROMISING

LINDA GAINES
Chief Scientist
ReCell Center
lgaines@anl.gov

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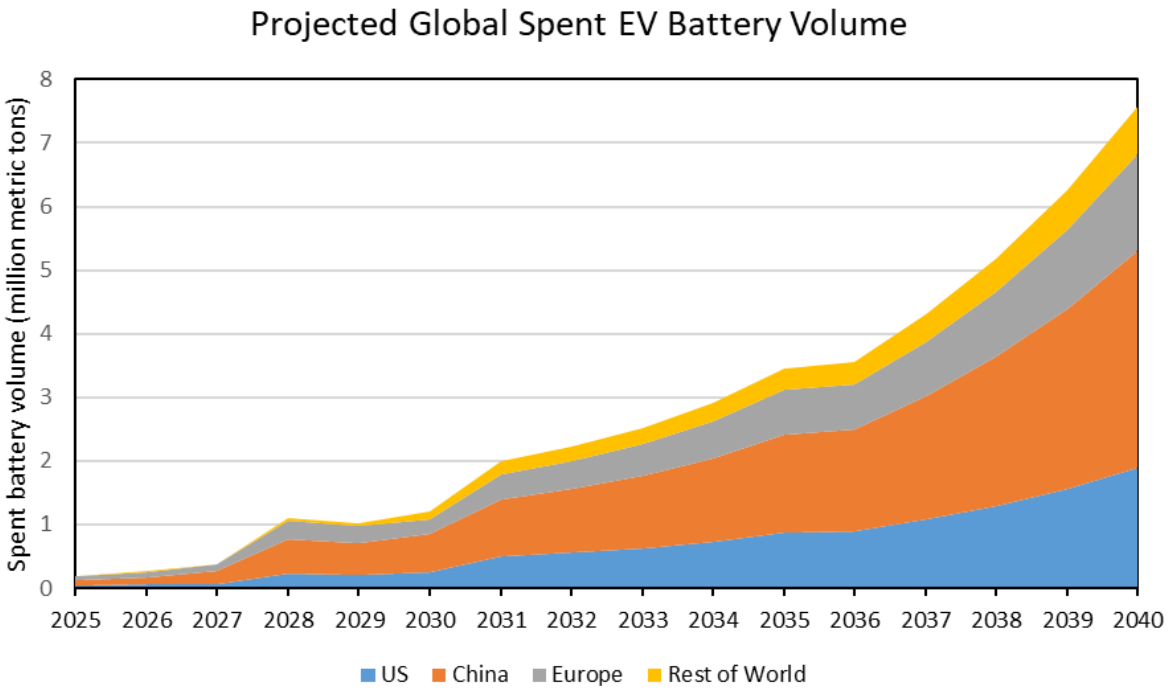
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
VEHICLE TECHNOLOGIES OFFICE

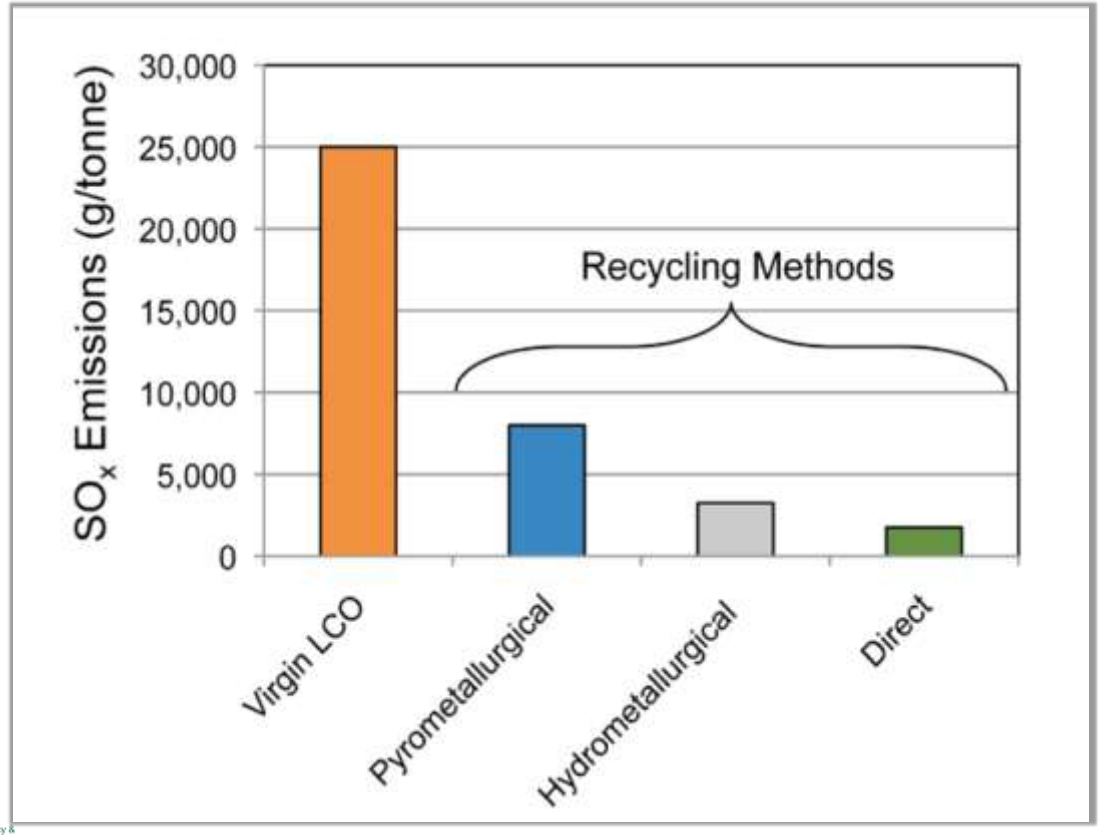
WHY RECYCLE?

- Recycling is a means, not an end
- Objective is to provide batteries with minimum impacts
  - Energy use/emissions
  - Resource depletion
  - Cost
  - Waste generation

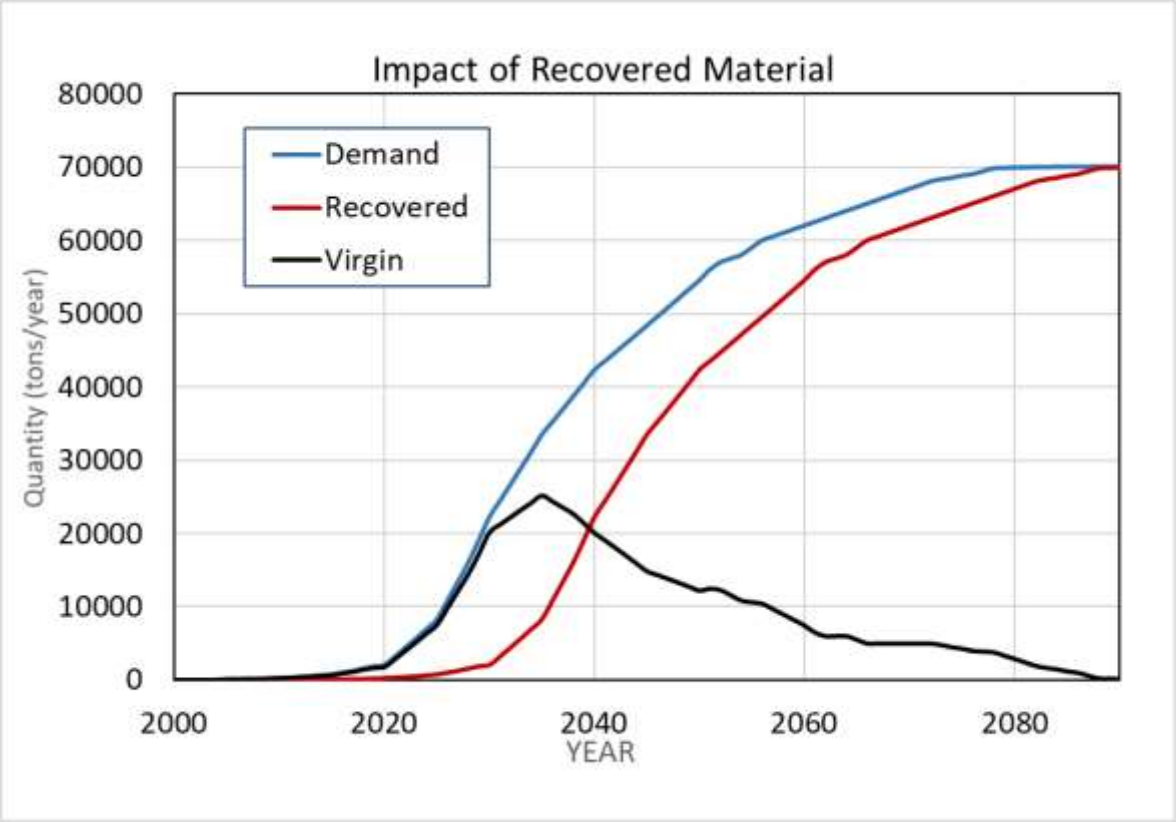


ANL projection (based on IEA global PEV projection)

RECYCLING METALS MADE FROM SULFIDE ORES REDUCES CATHODE ENVIRONMENTAL BURDEN

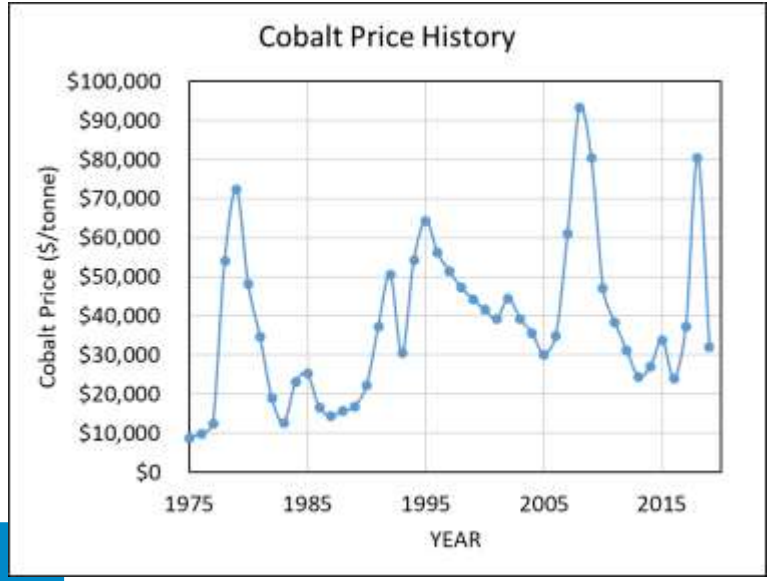


RECYCLING CAN REDUCE MATERIAL DEMAND… EVENTUALLY



COBALT SUPPLY COULD BE A CONSTRAINT

- Co is a key component of the cathode
  - Battery usage being reduced
- Half of the world's Co is in Congo
  - Political issues
  - Human rights issues
- Co price is volatile
- Current recycling efforts focus on Co
- Li is less of an issue

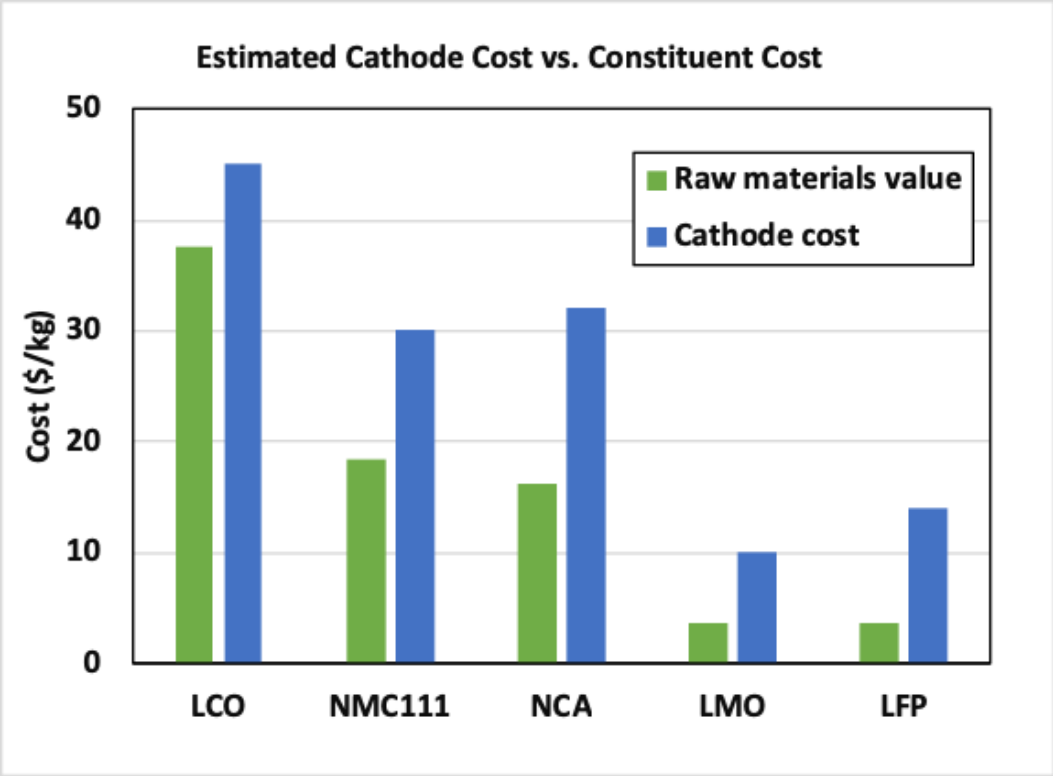


Element	Cumulative Demand to 2025 (1000 T)	Reserves (1000 T)	% of Reserves
Lithium	370	14,000	1.6
Cobalt	1,000	6,900	**14.5**
Nickel	1,200	89,000	1.3

CATHODE VIABILITY IS KEY TO ECONOMICS

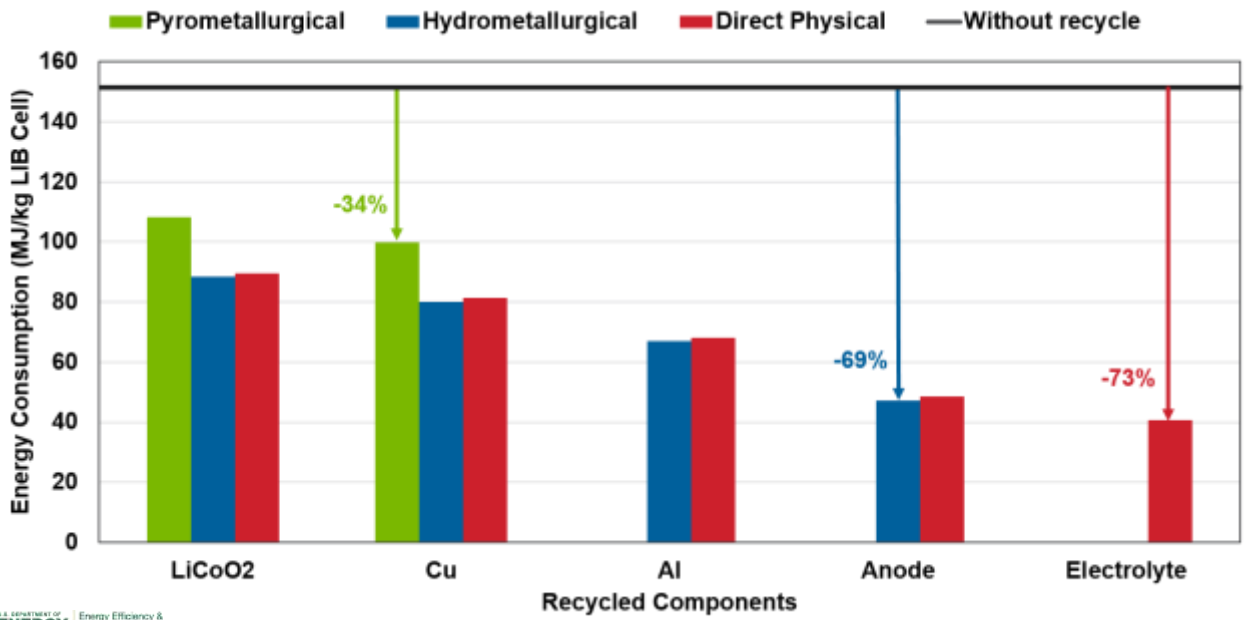
FOR CATHODES WITH REDUCED COBALT CONTENT

Cathode materials are valuable, even if constituent elements aren't

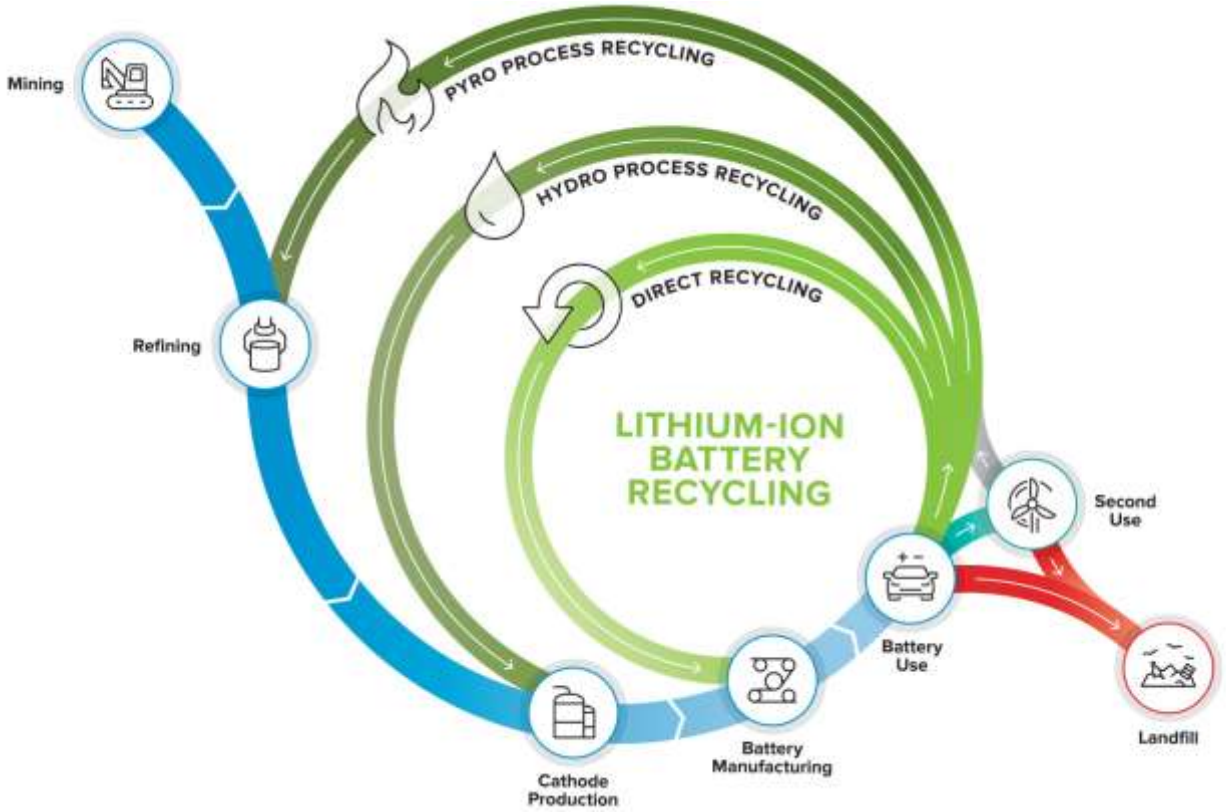


MORE MATERIALS RECOVERED MEANS LESS IMPACT

- Recycling reduces battery impacts
  - Energy to make
  - Emissions burdens and material costs
  - Demand for imported raw materials



LITHIUM-ION BATTERY LIFECYCLE



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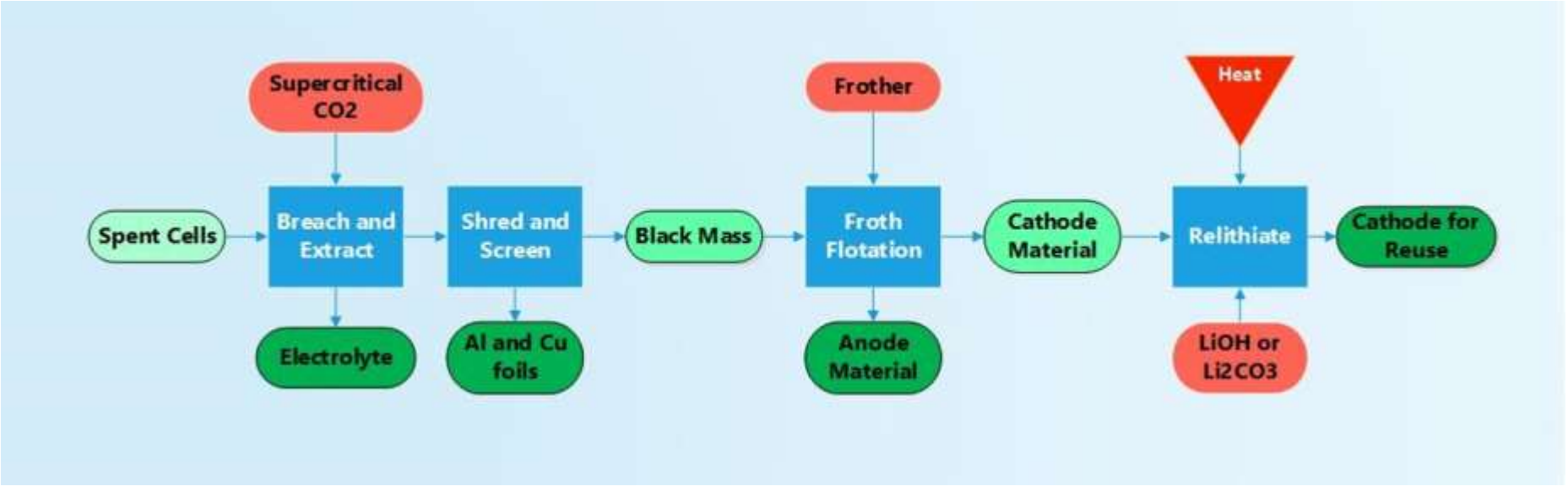
SEVERAL POTENTIAL REVENUE STREAMS ARE POSSIBLE

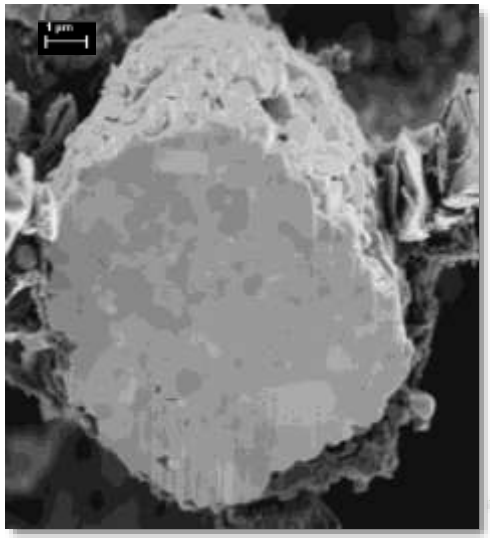
Some represent wastes avoided

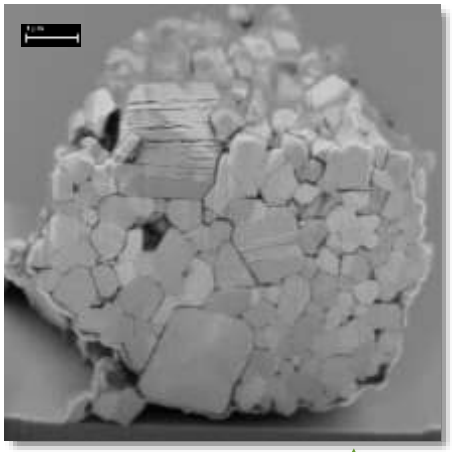


MOST BATTERY COMPONENTS COULD BE RECOVERED BY DIRECT RECYCLING

PROS	CONS
▪ Retains valuable cathode structure ▪ Can also recover anode, electrolyte, and foils ▪ Can be used for LFP ▪ Could be used now for home scrap, low volumes ▪ Low temperature, low energy ▪ Avoids most impacts of virgin material production	▪ Requires single-cathode input ▪ Product may be obsolete formulation ▪ Degradation may limit repeats ▪ Buyer must be assured of quality ▪ Not demonstrated on industrial scale

TECHNOLOGY MUST BE PROVEN





Courtesy of Daniel Abraham, Argonne

New NCA Cathode

After cycling

- Recycled material must consistently be good-as-new
  - Free from metal contamination
  - Retain crystal structure and layering
- Can SEI layer be removed without damaging structure?
- Will reconstituted cathodes duplicate original structure?
- Or can obsolete cathode morphology be updated?

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Thanks to:
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